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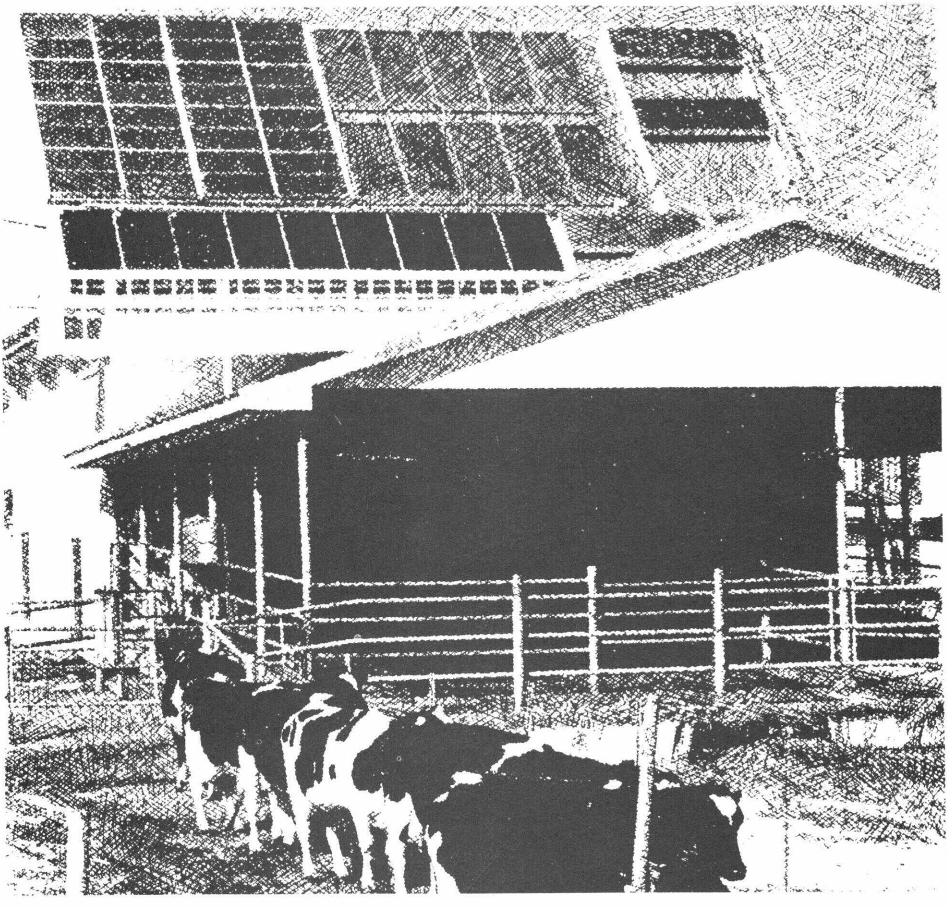
SOLAR HEATING FOR MILKING PARLORS



UNITED STATES
DEPARTMENT OF
AGRICULTURE

FARMERS'
BULLETIN
NUMBER 2266

PREPARED BY
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Washington, D.C. Issued September 1977

SOLAR HEATING FOR MILKING PARLORS

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Can solar energy be used effectively to offset the spiraling costs of running a modern dairy farm? This will depend on the circumstances of the individual farmer, but chances are, yes, it can. A well-conceived combination of energy conservation and solar heat can significantly reduce all the major requirements for energy in a milking parlor: for washing, heating, milking, and refrigeration.

The challenge of adapting this form of energy to the needs of dairy farming and of developing an overall energy supply and conservation plan specifically for milking parlors has been assigned to ARS scientists in a research project funded by the Energy Research and Development Administration (ERDA).

A complete system of solar heat and energy conservation has been installed at the milking parlor of the Agricultural Research Center in Beltsville, Md. (figs. 1 - 4). This system now provides about 75 percent of the total daily requirements of heat and hot water. It is constructed entirely of materials that are commercially available and reasonably priced. Thus, it serves as a model not only for further testing and experimenting, but also for constructing similar systems by individual farmers.

ENERGY CONSERVATION

The first step in developing a better overall energy plan is to analyze the present system with emphasis on lessening the energy requirements and eliminating waste and loss to the environment. Several major processes requiring energy in milking parlors are suitable for reduction by various energy-conservation techniques.

Precooling milk can lower the energy demands of the refrigeration

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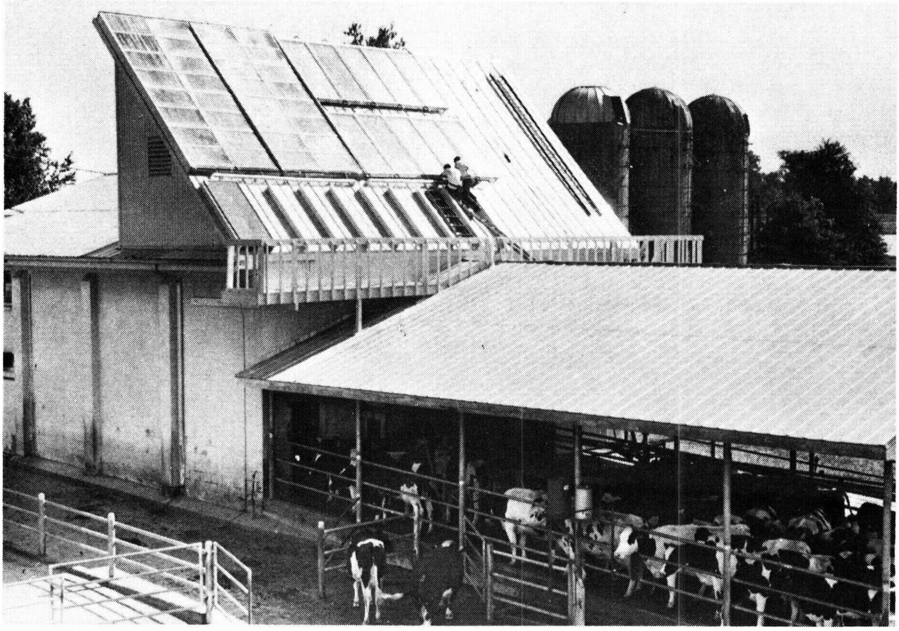

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Figure 1.—Overall view of the solar-heated milking parlor at the Beltsville Agricultural Research Center.

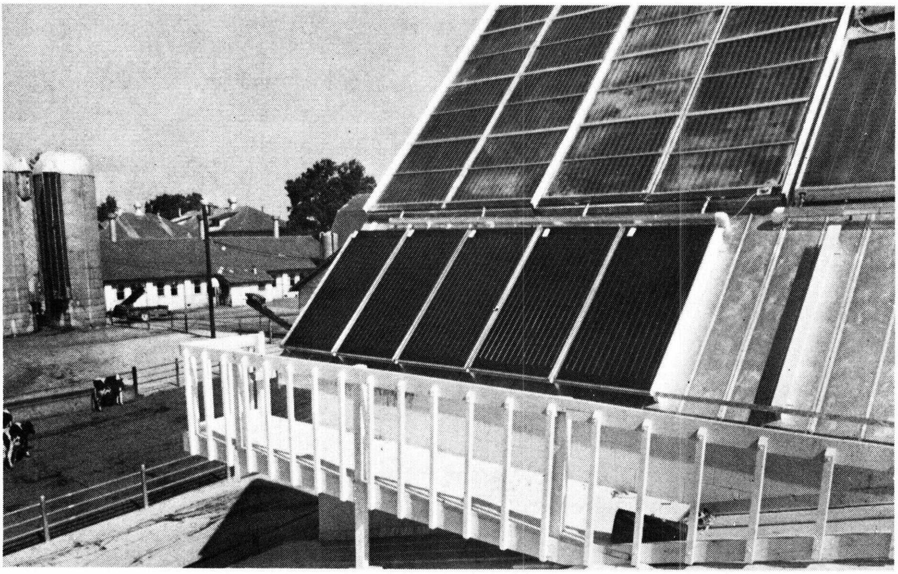

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Figure 2.—Flat-plate collectors mounted on the roof provide energy for heating space and hot water.

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Figure 3.—Several types of flat-plate collectors are placed on the support structure for testing and evaluation.

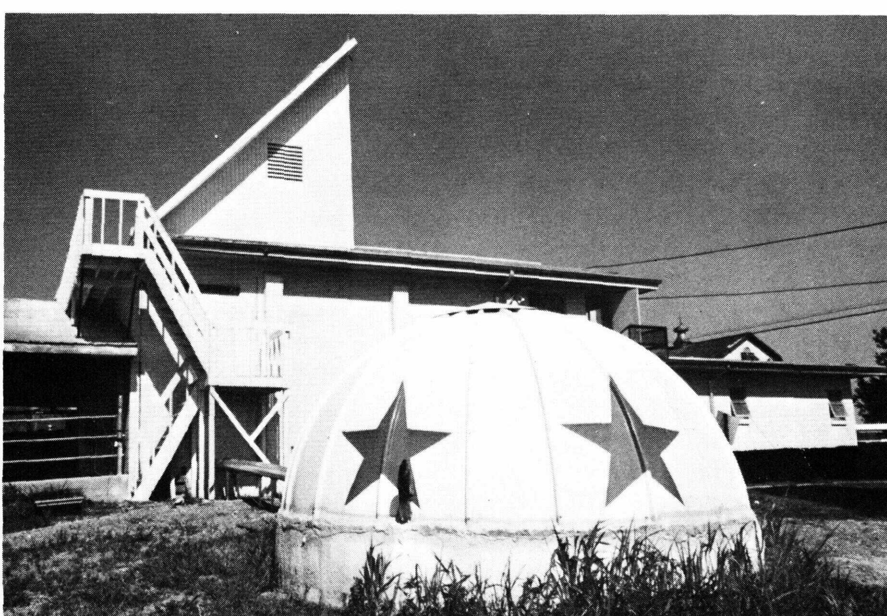

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Figure 4.—An insulated, partially buried tank stores heat for cloudy days.

unit from 30 to 40 percent. This can be done, for example, by arranging to have the milk pass from the milking machines through a plate or tube cooler cooled by well water.

The refrigeration unit and the exhaust pipe of the milking machines' vacuum pump both produce heat that, instead of being wasted, can be recovered and applied to hot water or space heating. Complete systems for conserving heat from the refrigeration plant are already on the market. It is estimated that 200 percent of the electric power used in refrigeration can be recovered as heat. This heat includes the heat removed from the milk as well as that generated by the machinery.

Insulation is always a major factor in heat retention and loss. If the building is not insulated, 50 percent of the space-heating energy will be lost. If water pipes are long and uninsulated, 25 percent of the energy used to heat the water will also be lost.

Finally, some consideration should be given to the efficiency of the equipment currently in use. Common energy wasters are oversized and worn vacuum pumps and gas-heater pilot lights that are left burning even in the summer.

PRINCIPLES OF SOLAR HEAT COLLECTION

All our energy comes ultimately from the sun, whether it be in the form of food, petroleum products, coal, or hydroelectric power. Sunshine can be converted directly into heat, and in this form, it has several advantages over conventional fuels: it is clean; it is nonpolluting; and it is virtually inexhaustible. However, it is also intermittent. Thus, one big difference between solar-heating systems and conventional ones is the necessity of storing energy in the form of heat. A suitable heat-storage tank should maintain desired levels of temperature for 2 consecutive days without direct sunlight when the heat supply cannot be replenished.

In solar-heating systems, the principles of operation are simple. Solar collectors are carefully situated where they will have maximum exposure to sunlight. A dark surface inside the collector absorbs the solar radiation and converts it to heat. Retention of this heat is made easier by a natural phenomenon known as the *greenhouse effect:* radiation which passes easily through glass or clear plastic in the form of light cannot pass back out in the form of heat, because the wavelength is much longer. It is thus trapped. A fluid (for example, air and water) passed through the collector transfers this heat either to fulfill an immediate demand or to be stored for later use.

Flat-plate solar collectors are the most common and readily available (fig. 5). These are comparatively inexpensive and easy to install. They can also function to some extent even on days that are overcast. Stationary collectors such as these are usually installed on a southfacing wall or roof and inclined to take best advantage of the winter sun, which is very low in the sky. For optimum performance, the collectors should be inclined above the horizon at an angle equal to the local latitude plus 10 degrees.

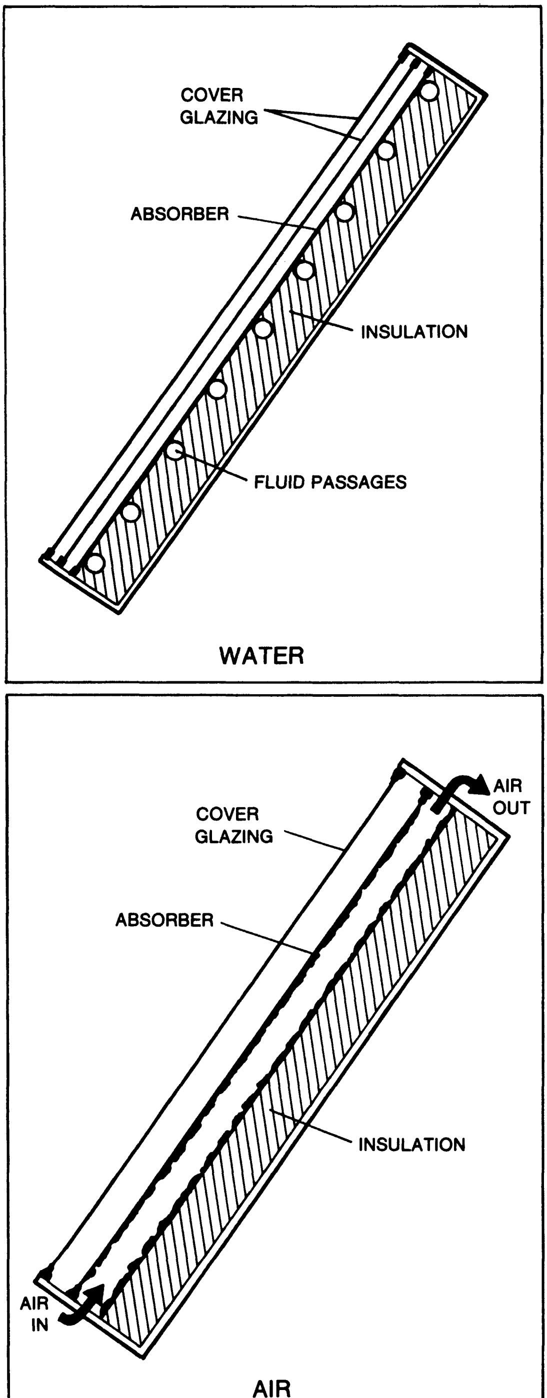

Figure 5.—Basic design of flat-plate collectors for water and for air systems.

Heat is captured better in collectors with a second cover. This is especially important where heat loss is a serious problem. In general, the better insulated double-glazed collectors are recommended for cold northern climates, but single-glazed ones are perfectly adequate for warm climates. Similarly, all collectors have insulating material along the underside, but those intended for use in cold climates should be especially well protected against heat loss to the building or the environment.

SOLAR ENERGY IS WELL SUITED TO DAIRY FARMS

Dairy farms require large amounts of fairly low-temperature heat, which solar energy systems are well suited to provide. Agricultural Research Service scientists at Beltsville have completed 1 year of their projected 4-year investigation into possible uses of solar energy for milking parlors. Although we have much to look forward to from this research, certain facts are already clear.

- Solar heating can supply most of the hot water needed in milking parlors, that is, it can supply all the water for preparing the cows and about half the energy needed to heat the water to higher temperature for cleaning equipment.
- Solar energy can provide most of the heat required to warm the working area during cold weather.
- A solar energy-heating system can be installed by a farmer using readily available materials for about $4,000, and the system should pay for itself in approximately 5 years and operate indefinitely.

Solar energy should be used along with energy conservation techniques to maximize the financial saving.

GUIDELINES IN THE DESIGN OF SOLAR-HEATING SYSTEMS FOR MILKING PARLORS

This publication explains some types of solar-heating systems that are applicable to dairying. After you've read it, you should be able to decide if solar energy is an attractive investment for you or if your resources would be better used for energy conservation or other improvements in your dairying operation. If you decide to proceed with solar heating, the next step will be to obtain manufacturers' catalogs and a design and construction handbook. These materials are available at many bookstores or by mail from lists supplied by the National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, Md. 30850.

Many factors must be considered in developing a system of energy conservation techniques and solar heating that will work for a particular farm: the geographic location and climate, the present source of energy, the cost, the size and construction of the milking parlor, and the prospects for future consumption and projected costs. Thus, designing a system that would be universally applicable is an impossible task; each farmer must review his circumstances and deter-

mine the best overall approach or combination of approaches to follow for a particular site. Table 1 shows several possible combinations and alternative approaches for easy comparison. These should be modified as appropriate for individual situations.

The complete solar-heating system performs four separate operations, each of which is accomplished by a subsystem: heat collection, storage, distribution and control, and utilization. Except for the energy source, storage requirement, and the low temperatures at which they operate, solar-heating systems are similar to conventional ones (fig. 6).

The first decision in planning a solar-heating system is on the nature and size of the heating demand to be supplied; both water and space (the milking pit), hot water only, or space only. The second is whether the transfer medium will be water or air. This will determine if the medium is to be moved through the system by pumps or fans, and if the storage tank is to be filled with water or with golf ball-sized rocks.

The next step is to decide the proper size of the components for a particular farm. This will depend on the geographic location, the size of the milking parlor, and the amount of heat to be delivered. Useful data on energy equivalents and typical examples follow.

Energy equivalents in Btu

1 kWh	=	3,400
1 Joule	=	0.00095
1 therm natural gas	=	100,000*
1 gal propane	=	95,000*
1 gal oil	=	128,000*

Energy requirements

Use	*Per cow-day*	*Range*
Hot water..........	0.6 kWh	0.3-1.2 kWh[1]
Space heating.......	0.6 kWh	0 -2 kWh[2]

[1]Varies with type of milking installation.

[2]Varies with location and season.

* Total heat as burned. Up to two-thirds of this energy is lost via flue or smokestack.

The size of the storage tank will depend upon the number of consecutive cloudy days to be provided for, the climate, and the percentage of total heating requirements to be met by solar energy. Systems with water as the transfer medium should be provided with 0.01 gal per Btu used daily (0.000038 1/J per day). For air systems, the storage should be

Table 1.–Solar heating and energy conservation systems

Item	Projected goals for–				
	Typical Midwest 70-cow farm				Experimental 200-cow farm for both hot water and space heating[1]
	Hot water only	Space heating only	Both hot water and space heating		
Type of system	Water	Air	Water and air	Refrigeration plant heat recovery.	Water
Energy sources (pct):					
Solar energy	50	50	50	– – –	50
Conservation	– – –	– – –	25	50	25
Conventional	50	50	25	50	25
Collectors:					
Type	Copper single-glazed selective absorber.	Homemade single-glazed.	Aluminum single-glazed nonselective	None	4 types, both single and double glazed.
Size	23 m^2 (250 sq ft)	46 m^2 (500 sq ft).	37 m^2 (400 sq ft)	None	92 m^2 (1,000 sq ft)
Cost (dol)	2,500	1,500	3,200		10,000
Support structure:					
Type	Open frame, on ground.	Built in	Mounted on roof.	None	New addition to building
Cost	500	None	200	None	13,000
Storage tank:					
Description	Inside building	Rock bed under cow platform in parlor.	Buried steel tank.	Auxillary hot water tank.	Partially buried insulated with 8 cm urethane foam.
Size	946 *l* (250 gal).	9.1 mt. (10 tons).	7,570 *l* (2,000 gal).	757 *l* (200 gal).	37,850 *l* (10,000 gal).
Cost	500	100	1,000		5,000

Circulation system:					
Description	8 *l* (2 gal)/min single loop; differential thermostat.	Fans and adjustable louvers; differential thermostat.	38 *l* (10 gal)/min to collectors 8 *l* (2 gal)/min to heaters; ductwork to use warm air from 2 hp refrigeration unit for space heating; differential thermostat for water heating, simple thermostat for space heating.	Heat exchanger on 2 hp refrigeration unit, available as package with controls, tank and compressor.	95 *l* (25 gal)/min to collectors 11 *l* (3 gal)/min to heaters heat exchanger on 6 hp refrigeration unit; electronic control and monitoring system including research instruments.
Cost (dol)	200	500	1,500	2,000 (add-on to standard system)	25,000
Total cost (dol)	3,700	2,100	5,400	2,000	53,000

[1] Located at Beltsville Agricultural Research Center, Beltsville, Md.

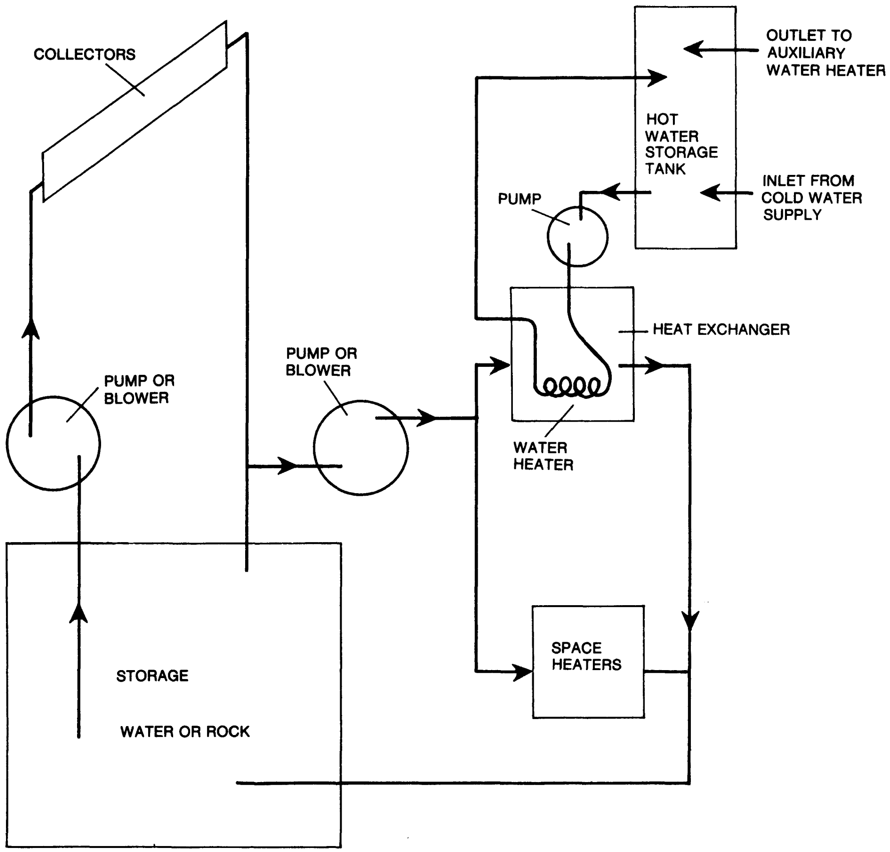

Figure 6.—General design of solar heating systems for milking parlors.

1.7 times the volume of the equivalent water system. For a water system on the average-sized farm, commercially available 2,000-gallon tanks should be adequate to provide heat for 2 consecutive cloudy days. All storage tanks should be insulated as well as possible, with several inches of a substance such as urethane foam.

In designing a circulation system for either water or air, the following factors should be considered.

1. The size of the ducts, heaters, and fans or pumps must be adjusted for the amount of water or air expected to flow through them.

2. The entire system should be well insulated.

3. Control should be automatic (a differential thermostat should be used to control circulation through the collectors, and conventional thermostats to control circulation to heaters or air dampers).

Systems in which water is used as the transfer medium require provisions in the design for:

1. Isolating units for repair or servicing.

2. Protecting potable water from contamination if the solar heat collection system is not built in accordance with good sanitary practice.

3. Draining collectors and exposed pipes to prevent damage from freezing.

In all systems where potable water is involved, special care must be taken to avoid any possibility of contamination. Water may be contaminated not only from leakage, for example, of anticorrosive or antibiological agents through a heat exchanger in a system with water as the transfer medium, but also from materials in direct contact with it. Pipes that carry drinking water should be made of a safe metal such as copper.

GEOGRAPHIC AREA AND COSTS

The geographic location of the farm is extremely important in the selection and design of solar-heating systems. It is possible to build a solar energy system that will supply 100 percent of the heat required at any geographical location. However, it may not be economical to do so. Thus, the systems shown here still depend to some extent on conventional sources of energy. The same percentage of total heating in the far North will cost about twice as much as it would in mid-United States and four times as much as in extreme southern locations. It should be remembered, however, that the cost of heating is probably proportionally greater in colder climates, so that, for example, a saving of even 60 percent in the far North may be greater financially than 100 percent in the South.

The relationship between cost and geographic area is shown in figure 7. In general, the requirements for mid-United States will be about twice those of hot climates and half those of cold ones. For example, the amount of flat-plate collector needed to produce 1 Btu per day is 0.0015 sq ft (1.4 cm^2) in typical climates, but 0.0008 sq ft (0.74 cm^2) in hot ones, and 0.0045 sq ft (42. cm^2) in cold climates. Based on 50-percent efficient collectors at current prices, costs per square foot will be about $10 for moderate climates, $5 for hot, and $15 for cold ones.

In northern climates freezing must be considered whenever water is used as the transfer fluid. Insulation helps to a certain extent, but provision must still be made for the water to drain from pipes outside the building to prevent heat loss and damage from pipes freezing at night when the system is not operating.

Wind and hail should also be considered. If the collectors were in a location where they would be subjected to a strong, constant wind, such as from a large body of water, the heat loss from convection would be far greater than normal. The collector could be protected from hail either by covering it with a screen or by substituting plastic for glass in the outer covering. Collectors with a glazing of plastic do not perform quite as well as those with glass, but they are more resistant to mechanical damage.

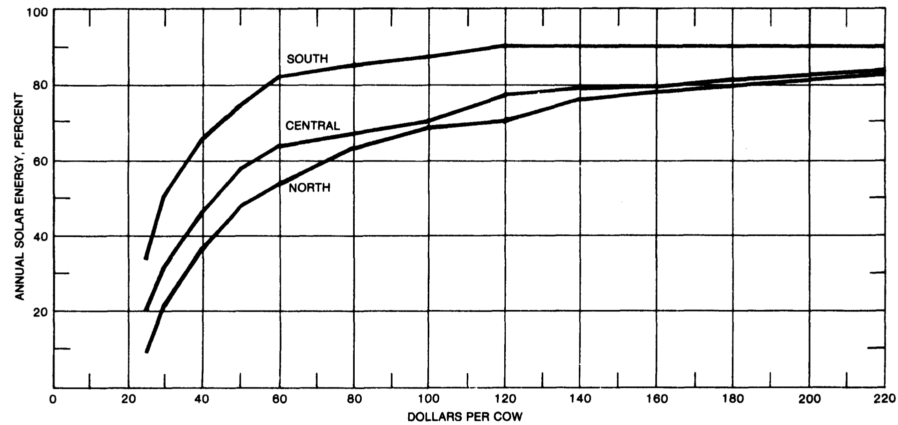

Figure 7.—Initial investment required for solar-heating systems in the United States (labor and mounting structure not included).

HOT WATER ONLY

The solar water heater is one of the simplest and most efficient applications of solar heat. In the warmer climates of the United States, solar water heaters have been used for decades. Many of these systems do not even require a pump. If the storage tank is located above the heat collector, the natural process of convection is sufficient to circulate the water. A one-way valve is necessary to prevent the process from reversing itself at night (fig. 8).

Some provision should always be made to drain the pipes in freezing weather. If a pump is used, it should operate automatically.

The size of the system will be determined by the amount of hot water needed, the temperature by which it is to be raised, and the geographic location. One method of approach is as follows:

- Number of gallons per day needed
- Times the number of degrees Farenheit it is to be raised by solar energy.
- Times 0.012
- Equals the number of square feet or collector required.

For example, to raise the temperature of 100 gallons of water 100° F will require 80.000 Btu, or 120 sq ft of collectors. That is, 0.0015 sq ft of collector for each Btu of energy per day to be collected in mid-United States. Use one-half as much area in the South and twice as much in the North.

Special precautions must be taken to eliminate any possibility of contamination of potable water by the materials used in the system (see p. 13).

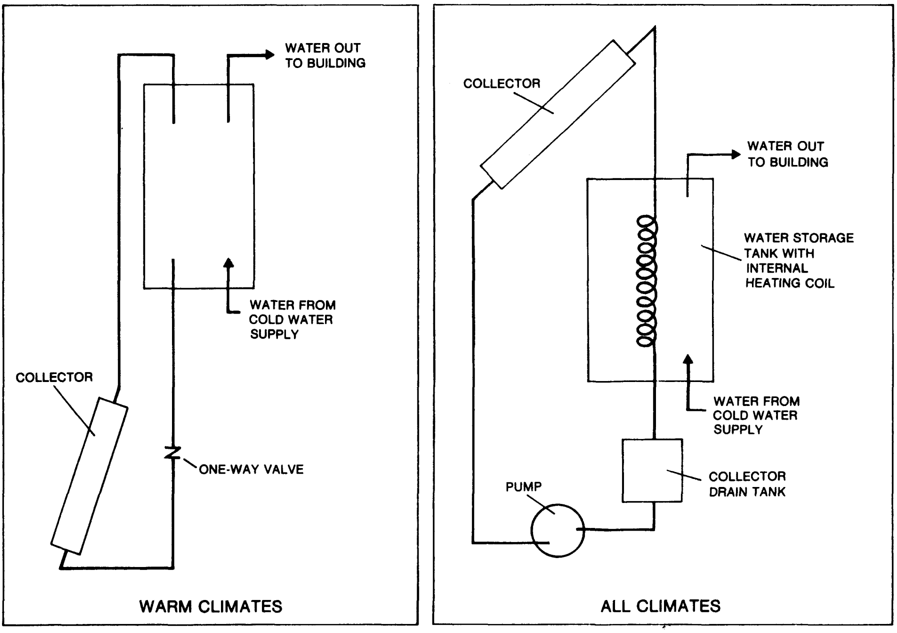

Figure 8.—Solar-heating systems for hot water.

SOLAR HEATING IN PERSPECTIVE

Solar-heating systems are particularly well suited to the requirements of dairy farms for large amounts of hot water and for low-temperature heat. The cost of installing these systems is expected to remain about the same for the next several years as more of them are manufactured and marketed. In many States tax incentives are in effect or being considered to encourage use of solar energy.

In areas where rising prices and scarcity of conventional energy sources are a major concern, individual farmers should consider their particular situation carefully and develop a suitable overall plan for energy supply and conservation. Solar-heating systems, which are becoming increasingly practical and economical, are an important alternative for a high percentage of the total energy requirements in the future.

For further information on the use of solar energy for milking parlors, contact the extention agricultural engineer at your local State land grant university or the National Solar Heating and Cooling Information Center.

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